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Terrain characterization for soils survey of Kucuk Menderes plain, South of Izmir, Turkey, using remote sensing and GIS techniques

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Abstract

Aerial photographs and satellite image interpretation, field investigation and laboratory analyses were integrated with a geographic information system (GIS) to recognize and display terrain and soils characteristics of Kucuk Menderes plain, South of Izmir, Turkey. Seven geomorphologic units were recognized, these being: recent shore ridges and marine beaches, schist and phyllite highlands, limestone highlands, foot slopes, alluvial fans, young alluvial plains and drainage basins. The data were integrated with topographic maps covering the area by using GIS tools. Contour lines were used to generate a digital terrain model (DTM) of the area. The DTM was processed to generate shaded relief. A Landsat 7 ETM satellite image was draped on the DTM to display the spatial scope of the investigated area. For the purpose of creating a soil map 15 observation points were dug representing the different physiographic units belonging to the study area. Soil mapping units have been identified by integrating physiographic units, field survey observations, morphologic description and laboratory analyses. Seven soil taxonomic units have been recognized, namely: *Typic Xeropsamments*, *Aquic Xeropsamments*, *Typic Xerofluvents*, *Aquic Haploxerepts*, *Typic Xerorthents*, *Typic Calcixerepts* and *Fluventic Haploxerepts*. Physiographic and soil maps with a scale of 1:25.000 were produced.

Key words: Kucuk Menderes plain, aerial photographs, satellite image, GIS, soil taxonomy.

Introduction

Many problems, which are now being recognized in natural and agricultural land systems, have arisen because of a lack of information on terrain and soils. Terrain and soils are a broad area, which emphasizes the investigation of land components and processes at a catchment level to provide a scientific basis for the coordinated use of soil, water, and vegetation by all land users in a sustainable and cooperative manner. One of the aims of this study was to test the usefulness of non-soil data (digital elevation models (DEM's), satellite images and the other digital data) for improving mapping efficiency and quality of soil maps.

Remote sensing and photogrammetric techniques provide spatially explicit, digital data representations of the Earth's surface that can be combined with digitized paper maps in geographic information systems (GIS) to allow efficient characterization and analysis of vast amounts of data. The future of soil survey lies in using GIS to model spatial soil variation from more easily mapped environmental variables (Sculla et al., 2003).

Jenny's (1980) well-known soil forming factor equation identifies the five factors of soil formation. Soil is characterized as a function of parent material, climate, organisms, and relief and time.

The equation implies that, by looking for changes in one or more of these factors as the landscape are traversed, one can accurately locate boundaries between different bodies of soil. Soil survey map units are based on a variety of landscape properties such as soil morphology, substratum type, slope, landform and flooding frequency. These properties have been chosen because they affect the land's capabilities and its response to management. Dengiz and Baskan (2010) indicated that soil formations were highly associated with topographic positions which influence on morphological and physico-chemical characteristics of the soils in local region. In their study, they found that young soils due to minimum soil formation and classified as *Entisol* / *Leptosol* while, *Inceptisols* / *Cambisol* and *Calcisol* on plateau position had the greatest degree of pedogenesis that have cambic and calcic main subsurface diagnostic horizons.

Because of the urgent need to control the existing degradation of soil, water and other land resources of the Kucuk Menderes valley, and to develop strategies for sustainable use, there is a strong demand for identifying terrain characteristics and land resources of this river valley. The Kucuk Menderes valley under investigation occupies a considerable portion of about 400 km^2 in the western part of Turkey. This valley represents the most important southern part of the province of Izmir, the third biggest city and the second harbour of Turkey. The main objective of the current work is to identify terrain and soil characteristics of the Kucuk Menderes valley through a comprehensive integration of different techniques, i.e. aerial photographs, ETM satellite image and digital terrain model (DTM) to provide a helpful guide for land use planners for prospective agricultural development.

Technological advances during the last few decades have created a tremendous potential for improvement in the way that soil maps are produced (McKenzie et al., 2000).

The literature review indicated that some physical and chemical soil characteristics are often estimated with remote sensing (RS) data. Factors such as iron-oxide content, soil organic matter content, parent material differences, soil moisture content, pH, calcium-carbonate, total carbon show relatively high correlation with RS data.

Hammer et al. (1995) used 10 m DEMs and 30 m DEMs with GIS to investigate the precision and accuracy of computer generated slope class maps for soil survey and land use planning. They suggested that slope class maps produced from the 10 m DEM appear to have great potential use for soil survey and land use planning.

Study area and methods

Description of the study area. This study was carried out during 2007–2009. The investigated area, which represents the Kucuk Menderes valley, occupies a considerable area of about 400 km^2 in the western part of Turkey. It is located between 37º 55 and 38º 25 N latitudes and between 27º 15 and 27º 47 E longitudes, representing the study area (Figure 1, Landsat 7 ETM, 2003 dated).

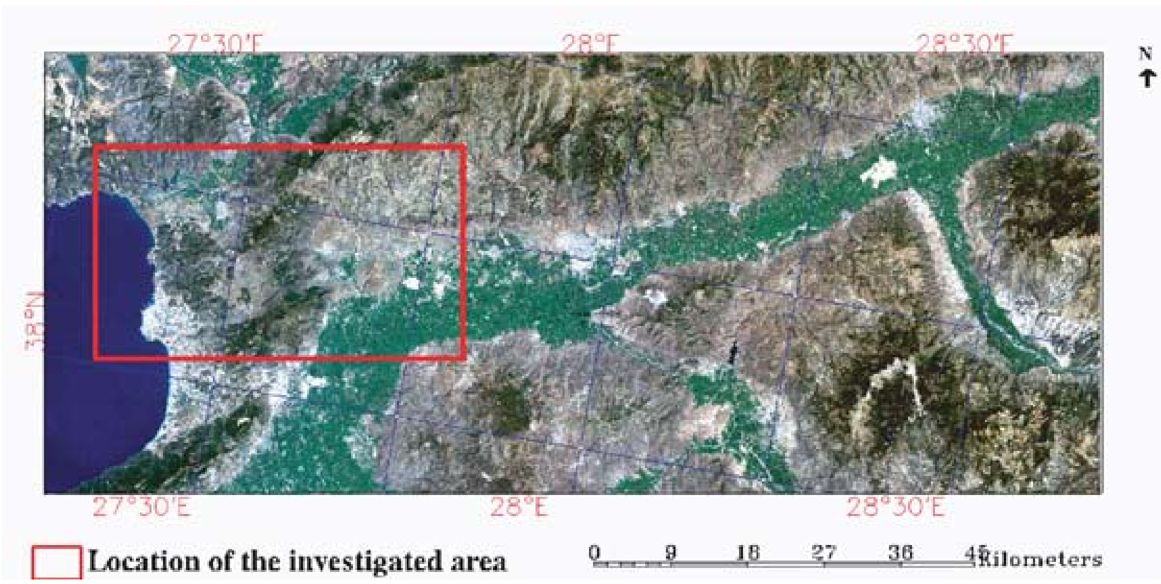

Figure 1. Location of the investigated area (Landsat 7 ETM, 2003)

The climatic zone. The Kucuk Menderes Valley has a Mediterranean tending towards continental climate. The climatological diagram as shown in Fig. 2 reveals that the rainfall curve is running below that of the temperature curve in 7 months, the mean annual soil temperature could be considered as less than 22ºC (16.3ºC) and the difference between mean summer and mean winter is more than 6ºC. According to the US Soil Taxonomy System (1999), the soil temperature regime of the studied area could be defined as Thermic and the soil moisture regime as Xeric except for the soils which have a high water table level, where the soil moisture regime could be considered as Aquic.

Geology and physiography of the study area. The Kucuk Menderes area belongs to the Menderes massif, the centre of which consists of gneiss and is of Precambrian age. Gneiss with some granite was found and it diffuses to southeastwards of the study area. On both sides, the gneiss is flanked by quartz-rich micaschists, probably of Paleozoic age (Izdar, 1972). Rocks of the southern part of the study area have a phyllitic and metaquartizitic character, they are probably of Devonian age. The limestone rocks, which occur northwards dated from the Permian era. Cretaceous limestone occurs often in the north part of the investigated area. The rhyolitic and dacitic rocks have not been dated but they were probably formed just before the Cretaceous period. Gravelly, layered deposits very rich in lime are found near highlands, which are defined as marls.

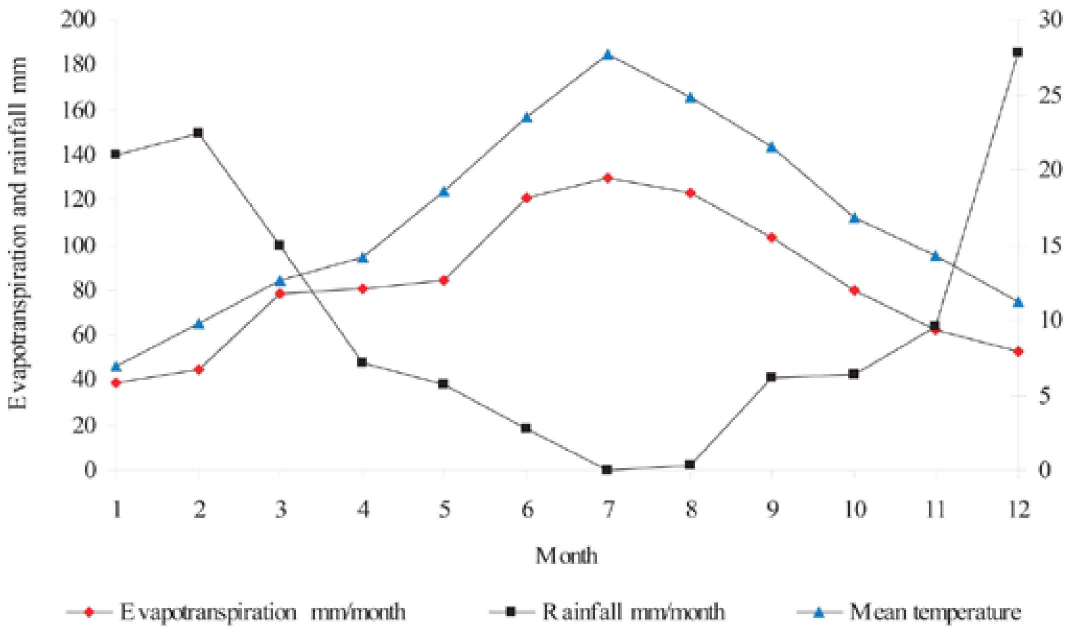

Figure 2. Climatological data of the investigated area

The valley is surrounded by two highland areas working together as catchment areas that supply tributaries of the Menderes with rainwater. The valley is separated from the other neighbouring valleys by two mountainous chains which define its natural boundaries. The Menderes penetrates a narrow valley forming a delta near Selcuk village, where the Menderes drains its water into the Aegean Sea. Seven physiographic units were recognized as: recent shore ridges and marine beaches, schist and phyllite highlands, limestone highlands, colluvial slopes, non dissected alluvial fans, young alluvial plains and drainage basins.

Methods. Panchromatic aerial-photographs (scale ± 1:40.000) dated to 1999, a Landsat 7 ETM satellite image, digitized contour map and 1:25.000 scaled topographical map have been used as the main materials.

The data provided in the digital soils map presented within this paper, constitute one of several essential components supporting the overall environmental assessment of the area. Digital data models, like the ones presented in Brady (2000), require accurate representation of soil material in the area as input.

The aerial photographs were studied stereoscopically and further divisions made using "the physiographic analysis" detailed by Goosen (1967) and Vink (1968). The main elements used were, slope, relief, grey tone, parcelling and vegetation. Figure 3 represents an aerial photograph that shows an important portion of the studied area.

Figure 3. An aerial photo shows to the Menderes delta

The Landsat 7 ETM image path/row: 180/34 dated 18 05 2001 was rectified, enhanced using ENVI 3.4 software and finally integrated with aerial-photos and DTM for displaying and demonstrating the most important terrain and soil characteristics. The test areas were chosen randomly for field work including each soil mapping unit in the research area.

A rapid reconnaissance survey was made firstly throughout the investigated area in order to gain an appreciation of the broad soil patterns, the landform and landscape characteristics. Longitudes and latitudes as well as elevation were defined by using GPS.

A total of 57 test areas were visited and soil profiles were studied during the fieldwork. Sixty disturbed soil samples were collected from horizons of 15 soil profiles for determining the different laboratory analyses. Morphological description was noted during the sampling processes. The soil samples were air-dried and then sieved through a 2 mm sieve in preparation for physical and chemical analyses. The soil samples were mechanically analyzed according to the international method. Soil colour was determined with the aid of Munsell colour charts, USDA, Soil Survey Manual (1993). The soil samples were chemically analyzed including electrical conductivity (EC), organic matter (OM), $CaCO_3$, pH (in saturated soil), according to (Soil Survey Staff, 1992).

Topographic maps and different mapping units as well as cities, lakes and roads were digitized using *Geomedia GIS* software. Digitized contour lines were used to create a digital terrain model (DTM) using an MGE Terrain Analyst module. The DTM was produced through two main processes; conversion of contour features to triangulated irregular network (TIN) using planner interpolation technique and TIN to grid conversion using bilinear interpolation technique. Shading parameters of the shading relief raster layer were as follows: sun angle (45), sun azimuth (315), sun intensity (98), ambience (2) and contrast (2).

The Landsat 7 ETM satellite rectified image was draped on DTM to obtain terrain characteristics of the investigated area using MGE Intergraph, a Terrain Analyst module. The interpretation lines as well as location of the observation points were transferred from the photographs to the physiographic map. The physiographic map was digitized and rectified using ARC VIEW 3.2 and DAK 3.5.2. The soil map was produced after plotting soil sets and their characteristics upon the physiographic map taking the results of laboratory analyses and field observation into consideration.

Results and discussion

One of the aims of our study was to test the use of non-soil data (DEMs, satellite images, digital contour data) for improving mapping efficiency and quality of soil maps, and to develop a pre-model for soil mapping. In the current study, the presentation and discussions will be grouped under the following headings: 1) aerial photograph interpretation and physiographic units, 2) digital terrain model (DTM), 3) soil mapping units and classification.

Aerial photo interpretation and physiographic units. One of the most common, versatile and economical forms of remote sensing is aerial photography. The main elements used were slope, relief, grey tone, parcelling and vegetation.

The physiographic units were recognized and delineated by analyzing the landscape extracted from the aerial photos with the aid of previous geomorphologic maps and field survey. The obtained results include generally three main landscapes: 1) coastal plain, 2) flood plain, 3) highlands.

There is an interference zone of fluvio-marine deposits formed between coastal and flood plains. Highlands surround both plains from the north and south, representing a very important source of nutrients and water supply. Aerial photograph interpretation resulted in the following physiographic units, as shown in Figure 4.

Coastal dunes and marine beaches. The Kucuk Menderes coastal dunes and marine beaches are accumulations of sediments deposited by waves and long shore currents in the shore zone of the Aegean Sea. They are typically composed of sand or shingle. Beach sediments along the coastline are well sorted with the size range at any one site being very limited so that sand beaches containing little silt or gravel and the mean sand grain size is coarser than the median one. There are four main sources for beach sediments: 1) local weathered and eroded sea cliffs, 2) the offshore zone from where sand may be derived, 3) calcareous sand and shell fragments, 4) materials found in the local Small and Big Meander river beds.

Young alluvial plains. Kucuk Menderes plain is formed of recent or young alluvial deposits occurring round the bases of many mountain ranges. Such a plain has not only partly low-angled alluvial fans, but also some of the characteristics of flood plains formed by braided rivers. This plain has been built up spasmodically during periods of severe erosion and glaciations in the surrounding uplands when sediments supply was at a maximum. The alluvial plain could be sub-divided into high, moderately high, moderately low, and low young alluvial plains.

Drainage basins. The Kucuk Menderes drainage basins may be considered as a collecting ground and storage container for precipitation, forming a system of routes by which rain water and sediment are transported to the Aegean Sea, and may be considered as an expression of the underlying geological structure of metamorphic rocks. The area of the Kucuk Menderes basin influences the amount of water yield; the length, shape and relief affect the rate at which water is discharged from the basin and the total yield of sediments; the length and character of the stream channels affect the availability of sediment for stream transport and the rate at which water and sediments are discharged. Two types of drainage basins could be identified according to their elevation, i.e. decantation basins and overflow basins.

Colluvial slopes. The general term for unconsolidated material deposited on slopes is colluvium. Colluvium of the studied area is part of the regolith and may contain particles of any size derived from uphill. Most colluvium is unsorted and unbedded unless it is the deposit left by slope-wash processes in the rainy seasons. It may lie upon old ground surfaces in which case a buried soil with definite horizons may be present within it and boulder or stone lines may be present if there have been distinct phases of deposition, with the stone line indicating an old ground surface. The term colluvium is used here for limestone. Soils represented in this physiographic unit are mainly loamy.

Alluvial fans. The alluvial fans of Kucuk Menderes plain are formed of fluvial deposits whose surface forms a segment of a cone that radiates down slopes from an apex where the depositing stream leaves its upland source area. The source area is the surrounding highlands and the depositional area is in a basin or sometimes at the margin of Kucuk Menderes plain. The alluvial fans in the investigated area have a great diversity of sizes, slopes, type of deposits and source-area characteristics. They are common in the highlands of the investigated area (humid and glaciated). The alluvial fans in the study area are dissected. They are subdivided according to elevation into high, relatively high, moderately high, moderate; moderate low and low non-dissected alluvial fans.

Highlands. The highlands of the investigated area are represented by rocky, hilly and mountainous land. This physiographic unit could be subdivided according to Boxem and Wielemaker (1972) into two groups, i.e. schist-phylite, granite and limestone highlands. These groups differ in height as well as rock types, with the highest mountain consisting of schist-phylite, called Bozdag, reaching 2157 m; while the highest mountain consisting of limestone is 1350 m.

Digital terrain model (DTM). Digital terrain modelling is a technique for deriving spatially explicit, quantitative measures of the shape character of topography (Weibel, Heller, 1991; Wilson, Gallant, 2000). Terrain analysis quantifies the relief component of models characterizing soil formation. Soil development, and its associated profile characteristics, often occurs in response to the way in which water moves through and over the landscape, which is controlled by local relief. Accordingly, ter-

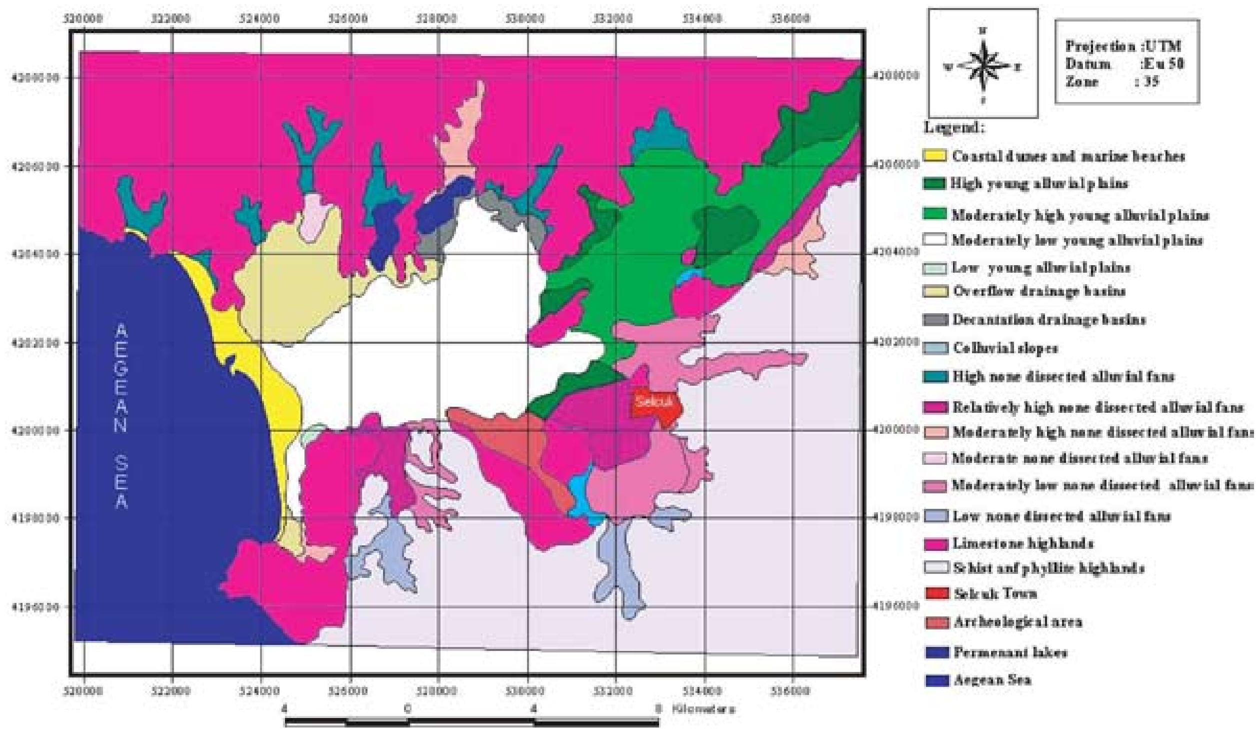

Figure 4. Physiography of the investigated area

rain analysis will be most useful in environments where topographic shape is strongly related to the processes driving soil formation. Several recent review articles have been specifically devoted to the role of terrain analysis in soil mapping (Ventura, Irvin, 1996; McKenzie et al., 2000).

The most basic and interesting geographical data type is the DTM. A DTM is a numerical representation of a surface based on a set of X, Y, and Z coordinates. A DTM contains only spatial elevation data in a regular gridded pattern in raster format. A feel for the character of the terrain can be more directly obtained by inspection of this type of image than by looking at conventional "flat" maps. As will be shown, 3D models rendered from DTM data related to the studied area can be extremely useful and versatile and can be used as a helpful guide to identify the surrounding terrain features. Geographic data models of soil variability and soil mapping were interpreted traditionally. Soil maps have been digitized to fulfil the need for soil data within GIS based environmental modelling research.

The advent of geographic information system based digital elevation modelling has facilitated quantitative modelling of catenas at local hill slope scales (McSweeney et al., 1994).

The problem with DTM data is that it does not contain anything other than elevation information. While useful for general visualization purposes, it can be difficult to locate objects precisely on the terrain model by referencing topographic features (since these can all seem to look alike). One way to improve a DTM is to overlay raster data on top. A better solution would be to overlay information over the terrain model.

Shaded relief. Shaded relief is a raster file based on the light source and the shading parameters, i.e. sun angle, sun azimuth, sun intensity, ambience and contrast. A shaded relief that was resulting from DTM shows terrain characteristics such as the surrounding highlands, Kucuk Menderes alluvial plain, alluvial fans, Menderes coarse, drainage basins, beaches and colluvial slopes as shown in Figure 5.

The improvement and easy accessibility of GIS technology has further facilitated spatial modelling of soil forming factors and provided a more quantitative method of soil characterization. Relief or landform shape can be characterized with the use of DEM. The terrain can also reflect indirectly part of the effects of the other four soil forming factors. Many successful applications of DEM and DEM-derived data have been made in large and medium scale mapping (Bell et al., 1994; King et al., 1999; McKenzie, Ryan, 1999; Sinowski, Auerswald, 1999; Chaplot et al., 2000; Young, Hammer, 2000; Chaplot et al., 2001).

Draping satellite image. Draping image creates a 3D terrain display from grid data which is superimposed with raster data. Another interesting extension of this method is to overlay satellite imagery over 3D DTM renderings. This powerful technique can yield impressive images and useful results with proper alignment of the satellite image with the DEM (georeferencing) as shown in Figure 6.

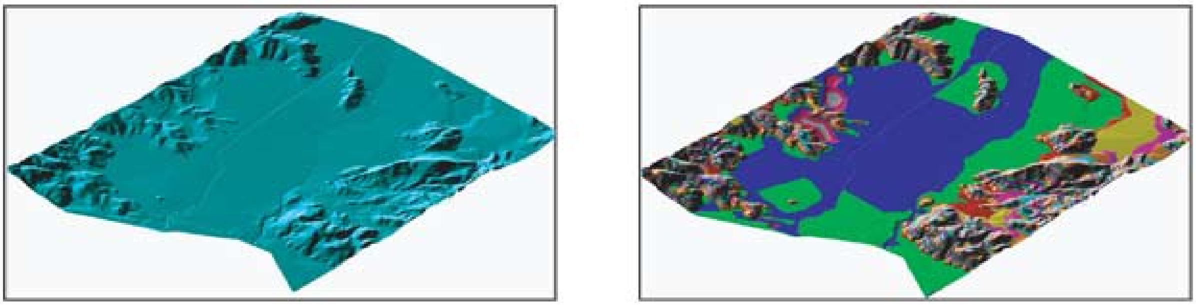

Figure 5 a** and **b. Shaded relief of the investigated area

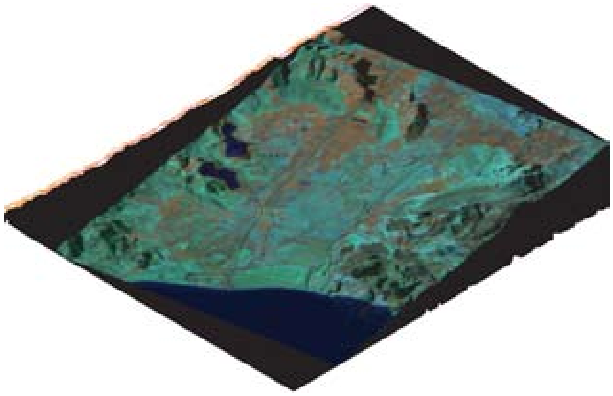

Figure 6. Satellite image with the DEM

Both physical factors (e.g. particle size and surface roughness) and chemical factors (e.g. surface mineralogy, organic matter content and moisture) control soil spectral reflectance (Irons et al., 1989).

Soil mapping units and classification. The present morpho-pedological study, which is based on aerial photo-interpretation, field studies, and analytical data revealed the soil sets using Soil Taxonomy (1999) as shown in Table 1 and Figure 7.

Traditionally, remote sensing has been used to classify soil units through photo-interpretation or digital image processing. Combining remotely sensed information with ancillary information such as thematic maps or vegetation cover can yield significant improvements (Cialella et al., 1997; Wanchang et al., 2000).

The landscape position and landscape characteristics also represent many of the vegetation, parent material, climate and time variations of the soil-forming environment. Soil and terrain relationships have been studied intensively, but due to their complexity it is still not fully understood (Wisocky et al., 2000).

Although individual images often show a tremendous amount of spatial detail, the use of multitemporal RS databases complemented with terrain information is concluded to be essential for deriving reliable soil classification categories (Dobos et al., 2000; 2001; McBratney et al., 2000).

Table. Physical and chemical analyses of the investigated area

Physio-graphic units	Pro-file No.	Hori-zons	Depth cm	Sand %	Silt %	Clay %	Texture class	pH 1:2.5	$CaCO_3$ %	EC Ds m^{-1}	Organic matter %	Soil taxonomy
1	2	3	4	5	6	7	8	9	10	11	12	13
Coastal dunes and marine beaches	P1	A	0–35	93.12	02.00	04.88	Sand	8.14	0.74	0.05	0.052	Typic Xero-psamments
		C1	35–150	91.48	04.00	04.52	Sand	8.51	1.02	0.05	0.052	
	P2	A	0–6	97.92	1.76	0.32	Sand	8.12	1.23	46.87	0.060	Aquic Xero-psamments
		C1	6–28	97.92	1.76	0.32	Sand	8.23	2.33	46.56	0.060	
High young alluvial plains	P3	A11	0–9	49.28	30.00	20.72	Loam	6.39	0.89	0.05	2.970	Typic Xerofluvents
		A12	9–23	45.28	20.00	34.72	Clay loam	6.05	0.96	0.05	1.470	
		C1	23–84	41.28	18.00	40.72	Clay loam	5.85	0.81	0.05	0.420	
		C2	84–116	49.28	22.00	38.72	Sandy clay loam	5.65	0.48	0.55	0.350	
		C3	116–200	51.28	14.00	34.72	Sandy clay loam	5.90	1.29	0.52	0.240	
Moderately high young alluvial plains	P4	A	0–24	53.12	40.00	06.88	Sandy loam	8.05	0.79	>46	0.748	Typic Xerofluvents
		C1	24–57	35.12	38.00	26.88	Loam	8.14	2.13	22.34	1.084	
		C2	57–73	43.12	40.00	16.88	Loam	8.05	4.58	18.44	0.568	
		Ck	73–120	55.12	26.00	18.88	Sandy clay loam	8.03	9.71	7.50	1.135	

Table continued

1	2	3	4	5	6	7	8	9	10	11	12	13
Moderately low young alluvial plains	P5	A	0–22	37.12	46.00	16.88	Loam	7.67	1.58	2.12	1.832	Typic Xerofluvents
		C1	22–40	29.12	50.00	20.88	Loam	8.02	1.18	1.32	1.187	
		C2	40–90	23.12	40.00	36.88	Clay loam	8.01	1.03	3.20	0.619	
		C3	90+	47.12	36.00	16.88	Loam	8.17	4.11	2.12	0.542	
Low young alluvial plains	P6	A	0–22	87.48	04.00	08.52	Loamy sand	8.25	0.67	0.05	0.103	Typic Xero-psamments
		C1	22–44	85.48	08.00	06.52	Loamy sand	9.05	1.10	0.48	0.052	
		C2	44–95	89.48	04.00	06.52	Sand	9.06	0.78	0.75	0.413	
Decantation drainage basins	P7	A	0–12	37.48	38.00	24.52	Loam	8.29	36.44	46.87	2.709	Aquic Haploxerepts
		Ck	12–38	45.48	42.00	12.52	Loam	8.46	10.72	36.87	0.568	
		C2	38–60	49.48	40.00	10.52	Loam	8.19	2.97	21.87	0.568	
Overflow drainage basins	P8	A	0–12	55.12	36.00	08.88	Sandy loam	7.56	2.92	46.0	1.290	Aquic Haploxerepts
		C1	12–42	65.12	26.00	08.88	Sandy loam	7.89	2.92	30.47	0.877	
		C2	42–52	36.12	51.00	12.88	Silty loam	8.00	4.11	10.00	0.361	
		C3	52–93	23.12	66.00	10.88	Silty loam	8.05	2.84	9.06	0.826	
Colluvial slopes	P9	A11	0–18	53.28	30.00	16.72	Sandy loam	6.10	0.82	0.05	1.300	Typic Xerorthents
		A12	18–57	49.28	24.00	26.72	Sandy clay loam	5.97	0.65	0.05	0.270	
		C1	57–81	43.28	30.00	26.72	Loam	5.20	0.61	0.05	0.200	
		C2	81–118	51.28	26.00	22.72	Sandy clay loam	5.43	1.55	0.05	0.150	
		C3	118–170	61.28	20.00	18.72	Sandy loam	5.40	0.73	0.55	0.150	
High none-dissected alluvial fans	P10	Ap1	0–12	52.56	32.00	15.44	Loam	7.35	15.19	0.97	1.10	Typic Calcixerepts
		A12	12–21	49.56	24.00	27.44	Sandy clay loam	7.36	16.61	0.86	0.52	
		Bk1	21–37	40.56	30.00	29.44	Clay loam	7.39	18.22	0.29	0.25	
		Bk2	37–86	40.56	30.00	29.44	Clay loam	7.59	25.52	0.53	0.20	
		Ck	86+	42.56	30.00	27.44	Clay loam	7.48	15.22	0.66	0.10	
Relatively high none-dissected alluvial fans	P11	Ap	0–31	63.56	24.00	12.44	Sandy loam	6.60	0.97	0.05	1.23	Typic Xero-psamments
		C1	31–57	65.56	24.00	10.44	Sandy loam	6.20	1.12	0.05	1.02	
		C2	57–76	69.56	20.00	10.44	Sandy loam	6.17	1.13	0.05	0.65	
		C3	76–112	67.56	20.00	12.44	Sandy loam	6.02	0.93	0.05	0.41	
		C4	112+	67.56	18.00	14.44	Sandy loam	5.97	0.60	0.05	0.33	
Moderately high none-dissected alluvial fans	P12	Ap	0–20	53.28	32.00	14.72	Sandy loam	6.38	0.90	0.05	1.92	Typic Xerofluvents
		C1	20–44	49.28	30.00	20.72	Loam	6.55	0.73	0.05	0.90	
		C2	44–67	61.28	26.00	12.72	Sandy loam	6.15	0.69	0.05	0.90	
		C3	67–83	67.28	18.00	14.72	Sandy loam	6.30	1.14	0.05	0.42	
		C4	118–170	61.28	20.00	18.72	Sandy loam	5.40	0.73	0.55	0.15	
Moderately none-dissected alluvial fans	P13	Ap1	0–15	47.28	32.00	20.72	Loam	7.44	31.65	0.70	1.72	Fluventic Haploxerepts
		A12	15–31	51.28	30.00	18.72	Loam	7.59	34.93	0.67	1.02	
		2Ab	31–40	47.28	32.00	20.72	Loam	7.65	40.50	0.64	1.20	
		2Bw	40–58	51.28	30.00	18.72	Loam	7.52	42.52	0.59	0.85	
		2Ck	58–70	63.28	24.00	12.72	Sandy loam	7.70	28.94	0.67	0.07	
Moderately low none-dissected alluvial fans	P14	Ap1	0–13	43.56	30.00	26.44	Loam	7.29	32.00	0.69	1.97	Typic Calcixerepts
		A12	13–34	48.56	32.00	19.44	Loam	7.39	28.67	0.05	1.04	
		Bk	34–69	47.56	28.00	24.44	Loam	7.56	40.15	0.58	0.97	
		Ck	69–83	50.56	26.00	23.44	Sandy clay loam	7.65	34.17	0.05	0.78	
Low none-dissected alluvial fans	P15	Ap	0–36	45.28	26.00	28.72	Sandy clay loam	6.42	1.29	0.05	1.26	Typic Xerofluvents
		C1	36–53	49.28	26.00	24.72	Sandy clay loam	5.85	1.05	0.05	1.02	
		C2	53–71	41.28	24.00	34.72	Clay loam	5.69	0.49	0.05	0.85	
		C3	71–110	39.28	22.00	38.72	Clay loam	5.65	0.30	0.05	0.52	

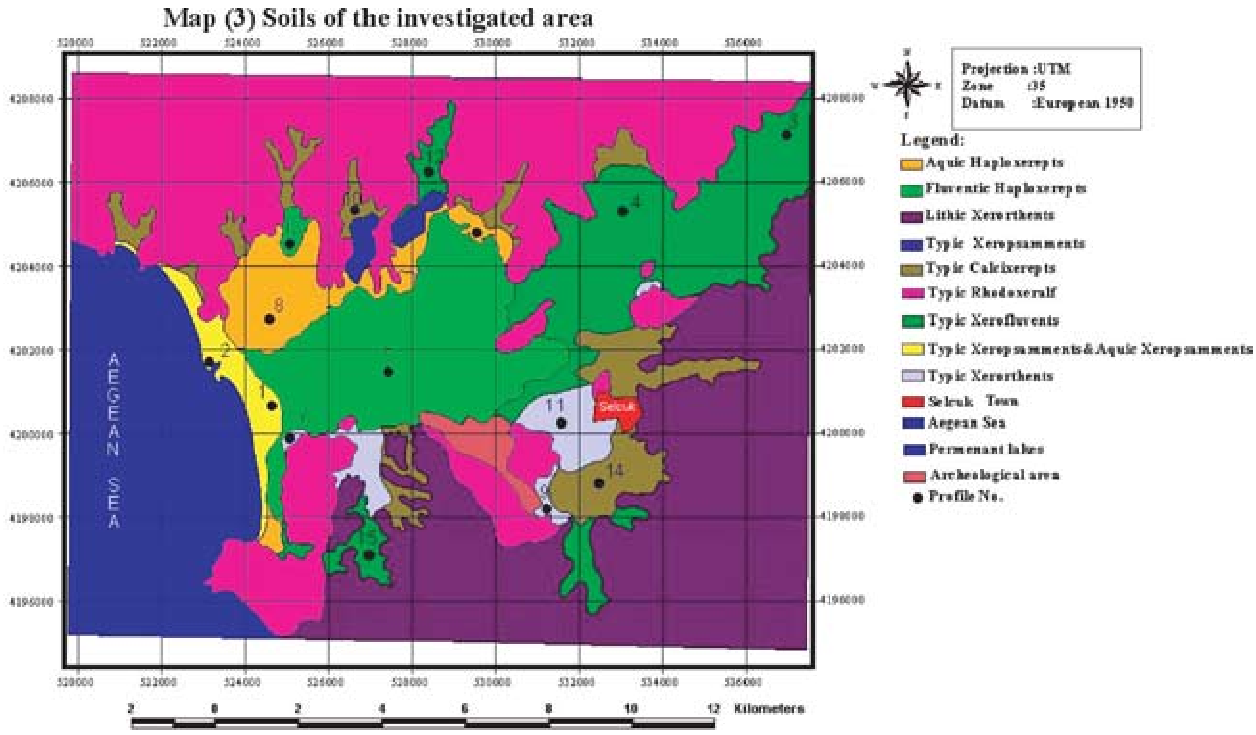

Figure 7. Soil map of the investigated area

Soils of coastal dunes and marine beaches. Marine beach, coastal dunes and inter-ridge depressions occur in a belt along the Aegean west of Selcuk. Dunes with a maximum height of 6 meters composed of sands and separated from each other by some depressions dunes are seemed to be parallel to the coast. It is noticed that soils of sand dunes are non-saline due to continuous leaching processes by the heavy rainy seasons as shown in profile No. 1. On the other hand undulating coarse textured non-calcareous soils are excessively or saline imperfectly drained representing the marine beaches as shown in profile No. 2. Due to the aforementioned data, the soils of coastal dunes could be classified as *Typic Xeropsamments* while the soils of the marine beaches are *Aquic Xeropsamments*.

Soils of young alluvial plains. Soils of the young alluvial plains correspond with the river plain of the Kucuk Menderes river. All deposits are young and more or less of the same age. Their subdivisions are mainly based on differences of soil texture and drainage status. Soil texture is ranges between fine to coarse as shown in soil profiles No. 3–6. The coarse-textured non-calcareous soils could be considered as excessively drained soils except in some places where saline imperfectly drained soils are found. The medium textured are usually well drained, while medium to fine textured non-calcareous soils are saline imperfectly drained soils as shown in soil profile No. 4. These soils could be classified under *Typic Xeropsamments* and *Typic Xerofluvents*.

Soils of drainage basins. The basins are found at the base of alluvial fans whose drainage outlet is blocked. The former lakes in these basins have been drained artificially. Most of the basins still have small lakes in their centres, varying in surface with the season. Soils of drainage basins are divided into soils of overflow and decantation drainage basins and represented by soil profiles No. 7 and 8. These two units could be distinguished through differences in their relative low elevation. Soil texture of the decantation drainage basin is loamy due to siltation processes that occur in these low lying soils, while it is sandy loam to silty loam in the soils of overflow basins. These soils are highly saline due to accumulation of salts from the neighbouring land and the effect of a high water table level. It is noticed that there are considerable amounts of shells and shell fragments, an inactive or inert form of $CaCO_3$, spread over the surface of decantation drainage basins as shown in soil profile No. 7. Soils of drainage basins could be classified as *Aquic Haploxerepts*.

Soils of colluvial slopes. These soils have a gently sloping to sloping colluvium at the foot of schist and phylite highlands. The soil texture of these soils is represented by different patterns of sedimentation such as sandy loam, loam and sandy clay loam in the successive layers of the studied soil profile No. 9. Non-calcareous well-drained soils developed on colluvium from schist. These soils could be classified as *Typic Xerothents*.

Soils of alluvial fans. Fan building processes are still active in the investigated area; sedimentation by numerous streams is the most important of these. Separate fans rarely occur. The individual fans are discernible near the mountains. Fans are subdivided on the basis of parent material in fans from which the alluvial material is derived from, i.e. schist and phyllite, and limestone Boxem and Wielemaker (1972). These soils are represented by soil profiles No. 10–15. The coarse textured non-calcareous excessively drained soils developed on alluvium from schist could be classified as *Typic Xeropsamments* as represented by soil profiles No. 11, medium-textured calcareous well drained soils developed on alluvium from limestone (*Typic Calcixerepts*) as represented by soil profiles No. 10 and 14, medium to fine textured with somewhat excessively drained soils developed on alluvium from schists (*Fluventic Haploxerepts*) as represented by soil profiles No. 13, medium to fine textured, well drained non-calcareous soils (*Typic Xerofluvents*) as represented by soil profiles No. 12 and 15.

Conclusion

In this study, aerial photographs and satellite image interpretation, field investigation and laboratory analyses were integrated with a geographic information system (GIS) to recognize and display terrain and soils characteristics of Kucuk Menderes plain, South of Izmir, Turkey. The results clearly showed that geomorphologic units condition strongly affects soil formation either directly or indirectly in the local region. In addition, topographic data collection, using traditional land survey methods, requires too much cost and is time-consuming. Today advanced computer programs such as geographic information system (GIS) and remote sensing (RS) contribute to the generation of topographic data in form of digital elevation models (DEM) to study terrain attributes that theoretically influence pedogenesis (Dengiz, Akgül, 2005; Graham, 2006). It is also very easy to update or modify data involved in GIS database in the future.

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Kucuk Menderes lygumos reljefo Pietų Izmire, Turkijoje, apibūdinimas dirvožemių tyrimams naudojant palydovines nuotraukas ir GIS technologijas

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Santrauka

Siekiant atpažinti ir pavaizduoti vietovės reljefą bei dirvožemius, būdingus Kucuk Menderes lygumai Pietų Izmire, Turkijoje, aeronuotraukos ir palydovinės nuotraukos, dirvožemių lauko tyrimų ir laboratorinių analizių duomenys buvo integruoti į geografinę informacinę sistemą (GIS). Atpažinti septyni geomorfologiniai vienetai: dabartinių krantų šlaitai ir jūros paplūdimiai, skalūno ir filito aukštumos, klintinės aukštumos, papėdės, aliuvinės vėduoklės, jaunos aliuvinės lygumos ir upės baseinai. Taikant GIS technologijas, duomenys buvo susieti su šios vietovės topografiniais žemėlapiais. Kontūrų linijos panaudotos vietovės skaitmeniniam reljefo modeliui (SRM) sukurti. Perdarius skaitmeninį reljefo modelį, sukurtas šešėliuotas vietovės reljefas. *Landsat 7 ETM* palydovinis vaizdas buvo uždėtas ant SRM, siekiant atvaizduoti tirtos vietovės erdvinį vaizdą. Dirvožemio žemėlapiui sudaryti buvo aprašyta ir ištyrinėta 15 dirvožemio kasinių, būdingų skirtingiems vietovės fiziografiniams vienetams. Dirvožemio kartografiniai vienetai nustatyti integruojant fiziografinius vienetus, dirvožemių lauko tyrimus, jų morfologinį aprašymą ir laboratorines analizes. Nustatyti septyni dirvožemio taksonominiai vienetai: *Typic Xeropsamments*, *Aquic Xeropsamments*, *Typic Xerofluvents*, *Aquic Haploxerepts*, *Typic Xerorthents*, *Typic Calcixerepts* ir *Fluventic Haploxerepts*. Buvo sukurti fiziografiniai ir dirvožemių žemėlapiai, kurių mastelis 1:25 000.

Reikšminiai žodžiai: Kucuk Menderes lyguma, aeronuotraukos, palydovinės nuotraukos, GIS, dirvožemių taksonomija.